

Measurement and Analysis of the Shocks Generated During Egg Production

JAY SINGH^{1,*}, CHRIS FERRIER² and PAUL SINGH³

¹*Associate Professor, Industrial Technology, Cal Poly State University,
San Luis Obispo, California, USA*

²*Graduate Assistant, Industrial Technology, Cal Poly State University,
San Luis Obispo, CA*

³*Professor, School of Packaging, Michigan State University, East Lansing, MI*

ABSTRACT: In their journey from the laying cage to shipments out of an egg production operation, table eggs encounter multiple shock events. While all agricultural commodities run the possibility of damage during the course of production, shell eggs are particularly susceptible to being cracked or broken during the production operation. A typical egg production facility experiences 2% to 7% checks (a partial mechanical failure to the egg shell) during handling, packaging and transportation of shell eggs. It has been estimated that the total losses to the U.S. egg industry due to checks and breakage of eggs during production amounts to over \$247 million per year. Research was conducted using a data recorder at Cal Poly Eggs (San Luis Obispo, California) to evaluate shocks sustained by the eggs going through the production operation. The production line for this operation resembles a typical commercial egg production facility. This study evaluated shock levels sustained by the eggs going through a typical production operation. The results and recommendations to help decrease damage due to shocks are presented in this paper. This data can be used to improve production lines at any egg production facility to decrease the amount of checks or breakage and to increase the profits.

1.0 INTRODUCTION

ACCORDING to the USDA, the U.S. egg production during June 2006 was 6.56 billion table eggs and the total U.S. egg production during 2005 was 76.98 billion table eggs [1]. In 2005, of the 213.9 million cases of shell eggs produced in the U.S., 68.2 million cases were further processed, 125.5 million cases went to retail, 18.2 million cases went toward food service use and 2 million cases were exported [1].

* Author to whom correspondence should be addressed. Email: jasingh@calpoly.edu

California Polytechnic State University's (San Luis Obispo, CA) egg production program currently has 14,000 chickens and produces more than 3.3 million eggs a year [2]. Cal Poly Eggs is an enterprise project and its sales have enabled the College of Agriculture's poultry program to be largely a self-funded. Profits from egg sales support supplies, equipment and students who gain work experience in the commercial egg industry. Cal Poly eggs are currently sold to restaurants and grocery stores from San Simeon in northern San Luis Obispo County to Orcutt in northern Santa Barbara County [3].

At the time of this study (April 2006), Cal Poly Eggs', laying operation was producing approximately 1.2 million eggs per year or 100,000 dozen eggs [4]. The operation was averaging 50 to 70 dozen checks (a "check" refers to a partial mechanical failure to the egg shell, which is a precursor to a complete breakage of the shell) per week at a loss of approximately \$4,200 annually [4]. This rate yields 2.6% to 3.64% checks annually. A majority of damage was due to improper production line settings and operator errors.

While the figures for Cal Poly Eggs are modest compared to large commercial producers, the operations are similar. The same test methods employed using the data recorder to map the degree of shocks in the production environment could be applied to larger facilities. Following is an overview of Cal Poly Eggs at the time of this study [4]:

- *Flock age*: 60 weeks
- *Flock Strain*: Hy Line W-36
- *Flock Breed*: White Leghorn
- *Feed*: Standard Layer Mash
- *Packaging*: Molded wood pulp flats stacked 5 high in B-Flute RSC cases
- *Holding Temperature*: 44.8°F (7.1°C)
- *Holding Humidity*: 99% Relative Humidity
- *Holding time*: 1 to 2 weeks
- *Production Volume*: 1.2 million eggs per year
- *Sales breakdown*: Currently 98% of eggs are sold in molded paper flats to restaurants

1.1 Production Flow at Cal Poly Eggs

A RFID (Radio Frequency Identification) enabled instrumented egg

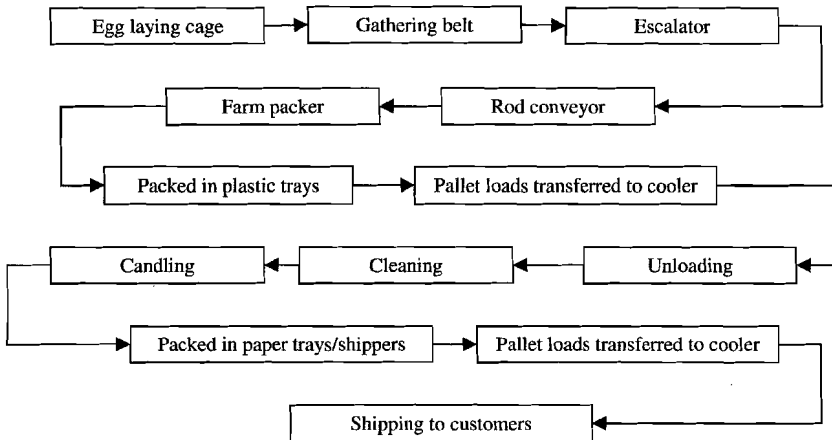


Figure 1. Flow Chart of Cal Poly Eggs Operation.

(Section 1.2) was used to monitor the production components at Cal Poly Eggs with a minimum of ten repetitions at each station. The results are described in section 3. The production flow at Cal Poly Eggs is as described in Figure 1. It is expanded upon in Section 2.0 of this paper.

1.2 Instrumentation

A variety of data recorders exist today with measurement capabilities such as temperature, pressure, relative humidity, light, speed, pressure, impacts and vibration. Depending on their capabilities these devices commonly involve such applications as field studies, transportation monitoring, troubleshooting, quality studies and general research. Recent advances and an increasing use of RFID technology in the past decade have enhanced the capabilities of data recorders by providing a portable and wireless means of capturing and transferring data. A data recorder with RFID features is typically designed for applications where portability and wireless data transfer is required. The communicating reader/writers can be mounted in a fixed location such as a portal or can be portable as well. One such device was obtained for a quality control application in the shell-egg industry.

While all agricultural commodities run the possibility of damage during the course of production, shell eggs are particularly susceptible to being cracked or broken during the production operation. In an effort to save a greater number of eggs and substantially increase the profitability

of egg operations at Cal Poly Eggs, Sensor Wireless Inc.'s "CrackLess Egg[®]" (Sensor Wireless; P.E., Ontario, Canada) data recorder was adapted for this study. The instrumented egg used was a battery powered replica of a Large Grade "A" egg which was equipped with a tri-axial accelerometer that measured shocks in G's (sample rate of 10 kHz), and transmitted the measurements via radio frequency (DC to 5kHz) to a handheld device (Palm[®] handheld computer) [5]. Once events were recorded, the handheld could be hooked up to the serial port of a computer and the files could be imported to the Agent QC[®] software that was included with the kit. A customizable chart was made available for each file as well as the raw and combined event data. The storage capacity of the handheld device was 36 MB or up to 100 files, depending on size, and a storage rate of ten samples for each channel per second [5].

The instrumented egg was designed to be placed anywhere in the egg gathering, conveying, or packaging systems so that it traveled amongst the real eggs through the production process, identifying abuse points and reporting location and magnitude of abuse instantly to the user in real time. If the data recorder dropped, rolled, or came into contact with a solid object, it sent a reading to a hand-held computer; the egg also transmitted a temperature reading and flagged high-pressure areas.

A study was conducted by the manufacturer of the instrumented egg for the Prince Edward Island Egg Commodity Marketing Board in 2002 [6]. This study was part of a bench marking for Large Grade "A" eggs most commonly available in consumer markets. The eggs in this study were rolled and dropped onto plastic, metal and padded surfaces from a height respective of the target threshold (45 G's and 85 G's) and visually inspected for shell damage (Figure 2).

Results of this study found that at an impact magnitude of 45 G's, Large Grade "A" eggs did not fail. However, when the same egg was subjected to more than three impacts at a level of 45 G's, it failed consis-

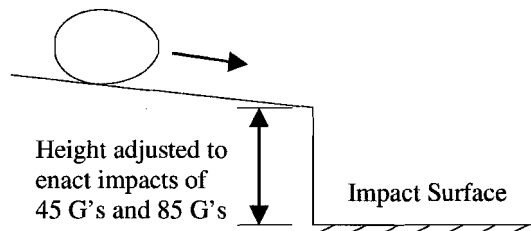


Figure 2. *Experimental Setup for Benchmarking Study.*

tently [6]. The same grade eggs when subjected to an impact magnitude of 85 G's also failed consistently by exhibiting visible cracks or damage on the egg shell [6]. This bench mark was re-established through testing at Cal Poly Eggs.

A study conducted at University of California, Davis estimated the economic loss due to checks and complete breakage [7]. This study estimated that unblemished eggs valued at \$0.55/dozen could revert to \$0.20/dozen due to checks and were usually processed for applications other than table eggs. This typically results in a loss of 0.3 cents/dozen of \$0.08/hen/year for each 1% of egg breakage [7]. For eggs completely damaged during production (no income), 1% is equivalent to 0.5 cents/dozen or \$.11/hen/year [7]. The same study, using 1998 production numbers, reported total losses to the U.S. egg industry due to checks and breakage of eggs during production amounted to \$247.5 million per year. In addition, there were other associated costs such as candling and the purchase of equipment to detect breakage, labor and packaging costs, costs for rehandling rejected eggs, clean-up and customer dissatisfaction and human health risks associated with consuming mishandled checked eggs.

2.0 METHODOLOGY

The test protocol used for this study evaluated the shock levels at each section of the production operation with a minimum of ten repetitions. The position and orientation of the instrumented egg was also varied to estimate as many conditions as possible. Following the testing, data was analyzed and suggestions developed to decrease checks. Data was collected in terms of average shock count, and minimum and maximum shocks for all components of the production operation. Explanation for testing conducted at various sections on the production line is provided below.

2.1 Test Protocols for the Production Line

Egg Laying

Egg laying was analyzed using three practical scenarios.

- a. *Cage to Empty Gathering Belt*: the instrumented egg was placed onto the cage floor and allowed to roll down onto the empty gathering belt.

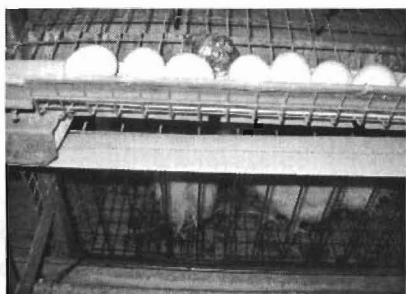


Figure 3. Cage to Loaded Gathering Belt.



Figure 4. Cage to Metal Support on Gathering Belt.

- b. *Cage to Loaded Gathering Belt*: the instrumented egg was placed onto the cage floor and allowed to roll down onto the gathering belt loaded with eggs (Figure 3).
- c. *Cage to Metal Support on Gathering Belt*: the instrumented egg was deliberately allowed to roll into the metal support (Figure 4).

Gathering Belt to Elevator to Rod Conveyor

The instrumented egg was placed on the gathering belt just upstream from the transition to the elevator. The eggs moved from the gathering belt onto the elevator (Figure 5) and down onto the rod conveyor (Figure 6).

Farm Packer

The instrumented egg was placed onto the rod conveyor upstream from the farm packer and the data was gathered until the test egg dropped into a thirty count plastic farm packer tray. Critical events to be moni-



Figure 5. Gathering Belt to Elevator.

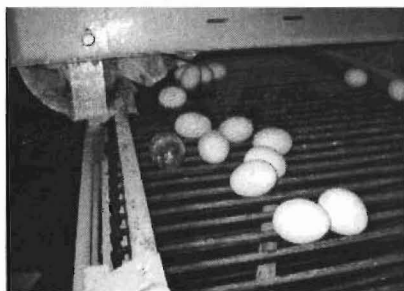


Figure 6. Elevator to Rod Conveyor.



Figure 7. Orienter at Farm Packer.

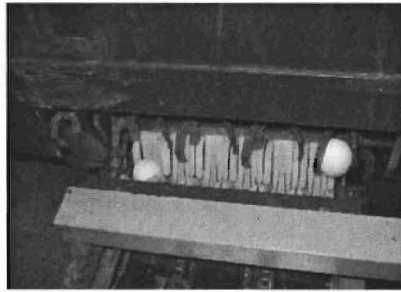


Figure 8. Eggs Picked Up and Dropped into Trays.

tored included the transition from rod conveyor to the farm packer, the transition to the orienter (Figure 7), pickup, and drop (Figure 8).

Palletizing from Farm Packer

The instrumented egg measured the forces produced along the conveyor belt before being stacked six trays high and finally being loaded onto a pallet.

Pallet Moving

The shocks experienced by eggs on a pallet as it is transferred from the farm packer to the holding cooler were monitored.

Loader

The instrumented egg was substituted for a real egg on a tray staged on the timing conveyor before the loader. This test focused on the forces created by the loader (Figure 9). The loader essentially unloads the eggs

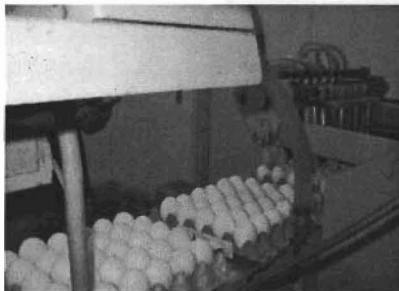


Figure 9. Loader Operation.

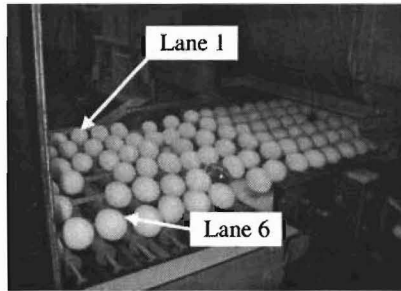


Figure 10. Transition between Washer and Candling Area.

from the farm packer plastic trays and loads them on the washer conveyor.

Washer Transition

Focusing on the transition from the washer to the candler, this part of the study spanned the distance past the loader. Trials were done for each of six lanes by substituting the instrumented egg for a real one. The farthest lane pictured in Figure 10 was referred to as “Lane 1,” or “Far Lane”, and the nearest lane as “Lane 6,” or “Near Lane.”

Candler

Shocks induced by transitioning into the candling area were recorded for each individual lane. Candles (Figure 11) are typically used to check egg quality and progression of embryos.

Sorter

The sorter picks up the washed eggs and grades them based on the measured weight. The eggs are then dropped into molded pulp trays.

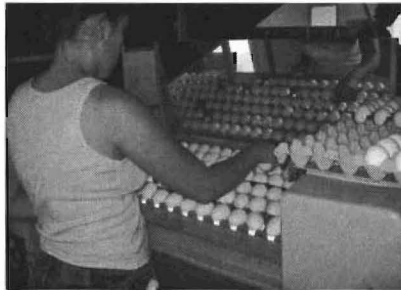


Figure 11. Candling Area.

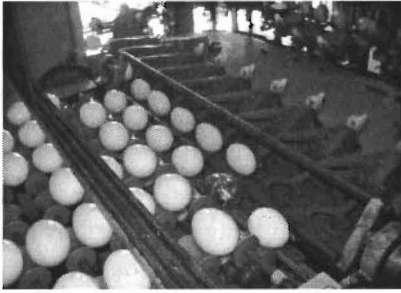


Figure 12. Eggs Transferred to Sorter.

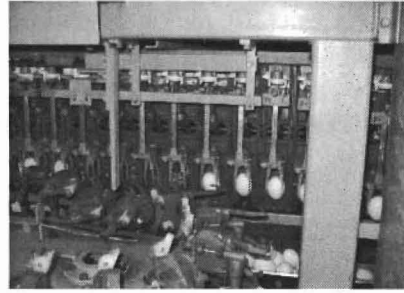


Figure 13. Eggs Moved and Sorted.

Two major events, the pickup and the drop were monitored. Figures 12 and 13 show the sorter operation.

Case Loading by Hand

The molded paper trays loaded with sorted eggs are then visually inspected and loaded into B-flute RSC shippers by operators (Figures 14 and 15).

Palletizing

The instrumented egg was incorporated into a full case of eggs and then moved from the packing platform to the pallet. The location of the test egg within the case was varied and the shock levels were monitored.

Transportation

Since the palletized cases of eggs are shipped within short distances to the customers and past studies have revealed absolutely no impact levels

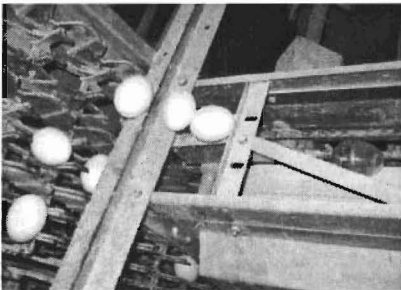


Figure 14. Visual Inspection and Case Packing.



Figure 15. Visual Inspection and Case Packing.

of concern [10], measurements of this segment of the distribution were not conducted.

2.2 The Effect of Drop Orientation

The complex structure of an egg which provides everything needed for the developing embryo is probably the best package provided by nature. An egg which can normally withstand extreme pressure due to its shape is also very susceptible to impacts. In addition to monitoring the various elements of the production line at Cal Poly Eggs, supplementary tests were also conducted to study the effect of orientation of the eggs on recorded shocks. Ten drops were conducted for each orientation drop, large end, narrow end and side, from three inches onto the rod conveyor (Figure 6). This location was selected due to the highest average shock count exhibited (Table 1). The drops were conducted on the large end, the narrow end and the side of the instrumented egg.

3.0 RESULTS

As identified in Table 1 and Figure 16, a highest level shock of 120 G's was observed for the production line event 4 between the gathering belt and the rod conveyor. Also of the fourteen operations mapped, seven displayed highest shock levels at or above the threshold value of

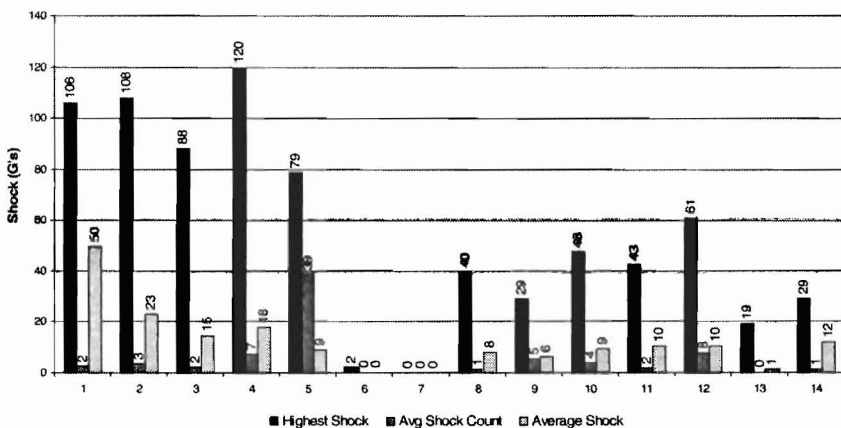


Figure 16. Graphic Presentation of Results from all Production Operations.

Table 1. Summary of Results from all Production Operations.

Data Summary	Production Line Event													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Highest Shock	106	108	88	120	79	2	0	40	29	48	43	61	19	29
Avg. Shock Count	2.2	3.2	2.0	7.1	39.0	0.2	0.0	1.1	5.3	4.1	1.8	7.5	0.2	1.0
Avg. Max. Shock	68.7	56.8	26.0	53.9	49.7	0.4	0.0	9.7	15.9	25.0	15.0	30.7	1.9	13.0
Avg. Shock	49.9	23.2	14.6	17.7	8.8	0.4	0.0	8.0	6.3	9.3	10.1	10.4	1.0	12.0
Avg. Std. Dev.	21.0	29.0	10.6	19.8	12.3	0.0	0.0	1.6	6.8	12.1	4.5	11.9	1.3	1.4

1 = Cage into Metal Support;

2 = Cage to Loaded Belt;

3 = Cage to Empty Belt;

4 = Belt, Elevator, Rod Conveyor;

5 = Farm Packer Loaded;

6 = Palletizing at Farm Packer;

7 = Pallet Moving;

8 = Loader;

9 = Washer Transition Lanes 1–5;

10 = Washer Transition Lanes 6;

11 = Transition to Candler;

12 = Sorter;

13 = Case Packing;

14 = Palletizing Cases

45 G's and four events above the critical value of 85 G's. This shows a need for considerable improvement at the production setup at Cal Poly Eggs.

3.1 Production Lines

For the egg laying and collection segment (events 1–3), all three scenarios tested produced shock levels beyond threshold value of 45 G's. The average shock of 49.9, observed during event 1, was the highest of the three. The eggs that impact the support rod while rolling down to the gathering belt have a possibility of cracking instantly or at a later event. During event 4 (gathering belt to elevator to rod conveyor), a highest shock during any operation of 120 G's was observed. Also the average maximum shock noted for this event of 53.9 G's was the third highest noted for all events. Most of the high level shocks for this event were observed at the transition between the vertical elevator and the rod conveyor, specifically at the point of drop on to the rod conveyor.

Event 5 (farm packer), delivered an average of 39 shocks per test, the highest for any event. This was due to the reliance on the back pressure of other eggs to advance the eggs across the transitions. With an average maximum shock of 49.7 G's the farm packer on average delivers a weakening blow to the egg shell, which may cause it to fail instantly or at a later event. At the loader (event 8), approximately 60% of the shocks observed were no greater than 3 G's. The highest shock of 40 G's could be an anomaly since the next highest shocks observed were considerably lower. Most of the shocks were observed as the eggs were released from the loader to the conveyor system.

For events 9 and 10 (washer transition), shocks were separately observed for lanes 1–5 and lane 6 after a preliminary observation of greater shocks in lane 6. The maximum shock of 48 G's observed for lane 6 was considerably higher than that for lanes 1–5 (29 G's). During the transition to the candler (event 11), a maximum shock of near threshold level of 45 G's was observed. This shock was observed in the farthest lane. Overall the shocks were not considered severe for this event. During its transition through the sorter (event 12), on average each egg received three shocks in the 20–30 G's range. The shocks tended to occur during pick up, drop and tray advance. A high of 61 G's was observed at this part of the production operation.

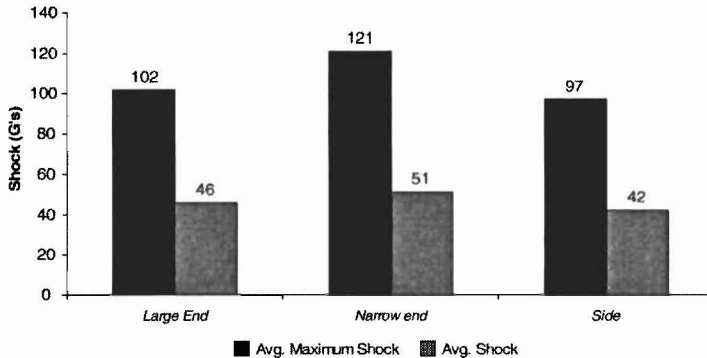


Figure 17. Graphical Representation of Drop Orientation Test Results.

3.2 Drop Orientation

As mentioned earlier, supplementary tests were conducted to study the effect of orientation of the eggs on recorded shocks. Ten drops were conducted for each orientation drop on the large end, narrow end and side, from three inches onto the rod conveyor. This location was selected due to the highest average shock count exhibited (Table 1). Table 2 and Figure 17 display the results of this supplementary test. A maximum average shock of 121 G's was observed when the egg was dropped on its narrow end and the least value of 97 G's was observed for egg dropped on its side.

4.0 CONCLUSIONS

A data recorder such as the one used in this study is a valuable tool for the egg production operations. Based on the observed shock levels at various components of the production line at Cal Poly Eggs, the follow-

Table 2. Summary of Results for Drop Orientation Testing.

Data Summary	Egg Orientation		
	Large End	Narrow End	Side
Highest Shock	159	168	170
Avg. Maximum Shock	102	121	97
Avg. Shock	46	51	42
Avg. Standard Deviation	44	51	44

ing suggestions were produced to decrease the damage levels and hence increase the profits:

- *Retrofit the metal support rods at the egg gathering belt area:* A solution to avoid high shock levels observed during events 1 (cage into metal support) and 3 (cage to empty belt) could be to route the support rod outside of the present location or to pad them.
- *Increase the egg gathering frequency:* For event 2 (cage to loaded belt), the frequency of egg gathering could be increased from once to twice per day. This could possibly decrease the egg on egg impacts.
- *Retrofit the landing area at the rod conveyor:* A solution to reduce the high levels of shocks observed when the eggs are transitioned from the vertical escalator to the rod conveyor could be to introduce a cushioned landing pad for the transition to the rod conveyor.
- *Evaluate the farm packer:* The construction and mechanism of the rod conveyor and the orienter material could be evaluated to decrease the high number of impacts. Also proper synchronization of the dropping of eggs into the farm packer tray should be looked at.
- *Evaluate the lanes for washer and candler transitions:* The construction and mechanism of the conveyor system for all lanes should be individually evaluated.
- *Evaluate the sorter speeds:* An estimated twenty to fifty dozen eggs are lost due to mishandling by the sorting equipment. The speed of all the operations occurring during this event need to be evaluated.
- *Egg Orientation:* Although, due to the nature of the moving mechanism in the production operations at Cal Poly Eggs, a majority of the eggs advance on their sides, some measures could be taken to ascertain that this occurs throughout the operation.
- *Feed management:* With damage levels reaching a predetermined point, it may be economic to switch to a feed with more calcium

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